Autonomous Wide Aperture Cluster for Surveillance (AWACS)

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Award Number: N00014-05-C-0208

LONG TERM GOALS

The long-term goal of the Autonomous Wide Aperture Cluster for Surveillance (AWACS) project is to demonstrate the use of a cluster of REMUS vehicles operating collaboratively for adaptive detection, classification and localization (DCL) of quiet targets in the complex littoral shallow water environment. As shown in Figure 1, the AWACS concept is comprised of at least three REMUS vehicles, each sensing the local environment, and a "master" (gateway) vehicle operating at the surface, equipped with GPS and an RF link. Onboard sensors sample oceanographic, bottom and acoustic features and the vehicles are able to communicate via AComms LAN with one another. This necessitates developing improved sensing and vehicle command and control capabilities to be incorporated into the REMUS vehicle and enhanced communications between the vehicles and surface assets. A key issue is the control and management of the vehicles, sensor systems (oceanographic, towed and hull-mounted acoustics arrays) and their associated communications networks, such that real-time dynamic control can be achieved for optimal DCL performance. A secondary goal is to utilize this technology for a cost-effective shallow water ocean acoustic environmental characterization capability.

OBJECTIVES

In FY07, a significant effort was spent on preparing for the New England Shelfbreak Test (NEST07) exercise that took place approximately 80 nmi south of Martha's Vineyard (see Figure 2) from May 25 to May 30, 2007. Specific objectives for the NEST07 sea test are given below:

- Improve capabilities of the acoustic systems (AS) deployed from the REMUS vehicle and SLOCUM glider. Begin integration of on-board DSP capability and characterize ability to autonomously detect, classify and localize quiet targets. .

- Continue development of mobile acoustic sources for transmission loss (TL) and DCL testing.

- Continue development of data assimilation algorithms for adaptive sampling to reduce uncertainty in the ocean/acoustic fields.

- Conduct very high resolution ocean and acoustic measurements in the highly variable shelfbreak environment.

- Evaluate the effects of this environment on the acoustic propagation and detection characteristics.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2007	**Annual**	**00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Autonomous Wide Aperture Cluster For Surveillance	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Ocean Acoustical Services and Instrumentation Systems (OASIS), Inc.,5 Militia Drive,Lexington,MA,02421**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**8**	

APPROACH

In order to accomplish the project goals, we have formed an interdisciplinary team with expertise from academic and scientific institutions, fleet operation support communities and manufacturers of oceans sensors and platforms. The principal team members, listed with their organizations and individual areas of expertise, are given in Table 1. During the NEST07 sea tests, the at-sea participants were primarily from OASIS, WHOI, NPS and BU.

The project utilizes an extensive build-test-build technical approach, in which AWACS components, algorithms and adaptive methodologies are designed, built, tested and evaluated, then modified and rebuilt in response to the test results. Tests and evaluations occur in controlled laboratory environments, and at sea. The basic scientific research concentrates on formulating and testing new hypotheses and methodologies. In addition, scientific simulations and engineering designs will be carried out prior to and following the at-sea experiments. This approach provides the AWACS team with the ability to get hands-on experience with the REMUS vehicles and sensors, shake down system components, algorithms and methodologies, and identify and fix potential problems.

WORK COMPLETED

Recall (from last year's annual report), that extensive tests were conducted during SW06 in August and September of 2006 off of the New Jersey shelfbreak. During this test, the AWACS team successfully conducted high resolution oceanographic and acoustic measurements in the New Jersey shallow water environment, using 12 Scanfish surveys (>160 hrs) to characterize the Shelfbreak Front (SB) variability and 12 OMAS Acoustic tests (>60 hrs) to characterize the effects of the SB front on acoustic propagation, including detection performance. Adaptive sampling was employed to resolve the SB Front and it was then exploited for improved acoustic transmissions. Objective maps, combined with data assimilation at shore, provided sampling ideas. The team quantified regions of TL uncertainty (scales for horizontal isotropy and translational invariance).

Following SW06, several preliminary tests were conducted (in January and February of 2007 off of Cuttyhunk Island and April 10-13 in the Gulf Stream off of Miami) to test and refine the integration of the OASIS Acoustic System (OAS) with the Glider and the REMUS vehicles in preparation for the NEST07 test.

The primary AWACS components used during the NEST07 at-sea test are shown in Figure 3. They are two acoustic systems (separately built by OASIS and BU); two REMUS vehicles (owned by WHOI), one equipped with the BU array and the other tasked to perform physical oceanography measurements; two SLOCUM gliders (leased to OASIS), one equipped with the OAS and the other tasked to perform physical oceanography measurements; multiple OMAS (OASIS Mobile Acoustic Source) vehicles with associated LBL sonobuoy tracking hardware, including expendable planar arrays; and one Hydroid gateway buoy to relay information and instructions to/from the REMUS vehicles.

Preliminary results from the NEST07 experiment include:

- Successful cluster operations involving both REMUS, both Gliders, and two OMAS with multiple sonobuoy receivers (See figure 3)

- REMUS deployment and recovery from shipboard cranes. No small boats needed (Except for Gliders)

- Autonomous detection and bearing tracks transmitted to ship via Freewave and Iridium.

- Adaptive sampling of the cold pool duct for long range detections

- Detection of an anomalous slope eddy with shelf water above core

- Preliminary localization with Glider/OAS and REMUS/PAS (Post Processing)

The preliminary results from the sea trial are summarized in the NEST07 cruise report listed in the references.

An AWACS team meeting was also held on September 11th and 12th at OASIS in Lexington, MA. This meeting served to reconnect team leaders and facilitate test planning for 2008.

RESULTS

Some of the results of the NEST07 Experiment are shown in Figures 4 - 6. Figure 4 shows the NEST07 operation area, with the bathymetry and reconstructed OMAS tracks for the 8 runs. The OMAS tracks were selected based on objective maps derived from the measured oceanography and ocean adaptive sampling of environmental keys (i.e. Shelfbreak cross-shelf position, cold pool duct and mixed layer depth).

Transmission loss data obtained via the OMAS and sonobuoy receiver system can be seen in Figure 5. The figure shows TL vs. bearing results for two different OMAS vehicles, one transmitting within the cold pool duct (red) and the other transmitting below the duct (blue and green). The figure shows that a 5-10dB reduction in loss was realized by positioning the source within the duct. It also shows that in general, TL in the NEST07 region is more anisotropic than that seen during the SW06 test.

The NEST07 test also involved the shakedown and preliminary testing of autonomous detection, classification and localization (DCL) using software embedded on a DSP chip within the Glider. These tests only considered the detection and tracking (in bearing) part of the problem, with classification and localization development and testing planned for 2008. Figure 6 shows the measured autonomous OMAS detection bearing tracks (Solid black line) with the ground truth (Dashed red line). The ambiguous OMAS1 track is also shown (Dotted black line). There is good agreement between the ground truth line for OMAS 1 and the OMAS 1 track relayed from the Glider. It is hoped that even better bearing accuracy can be obtained through the use of a heading sensor mounted on the OAS itself, with tests of this system planned for 2008.

IMPACT/APPLICATIONS

The development of an OASIS Mobile Acoustic Source and AUV AS (off the REMUS and SLOCUM glider) will provide the Navy with important off-the-shelf tools for autonomous surveillance and obtaining in-situ TL in oceanographically complex environments. The source will also serve as a

useful anti-submarine warfare training tool, acting as a realistic target source while also providing range information to sonar operators.

The demonstration and use of the REMUS and Glider vehicles towed arrays will provide the basis for future AWACS concept testing, including collaborative system experiments and evaluation. The integration of additional sensor and processing capabilities onboard the vehicles will provide a valuable tool for oceanographic research in littoral and continental shelf regions.

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Abbot, P., Gedney, C., Morton, D. and Emerson, C.," Mobile Acoustic Source for Underwater Acoustic Measurements," OCEANS 2006, Boston, MA, September 2006. [published]

Table 1 – AWACS Team Members and Roles

Organization	Key Individual(s)	Roles
OASIS	Abbot	Test Planning and Coordination, Data Collection and Analyses Mobile Source, Towed Array for REMUS and Glider Acoustic System Performance and Uncertainty
	Gedney/Premus	Array and Adaptive Signal Processing
WHOI	Lynch	Ocean Acoustics and Sampling, AUVs and Control
	Gawarkiewicz	Physical Oceanography/Ocean Sampling
BU	Carey	Array Processing and Performance Analysis
NPS	Joseph	Environmental Measurements/Estimation and Adaptive Search
HU	Lermusiaux	Ocean Science and Modeling, Adaptive Sampling and Search, and Coupled Data Assimilation
Duke	Krolik	Collaborative and Adaptive Signal Processing
ProSapien LLC	Smith	Multiple Vehicle Control and Reconfigurable Networking

*Note: each organization in the AWACS team has submitted a separate Annual Report to ONR and this report focuses on the OASIS work in FY07.

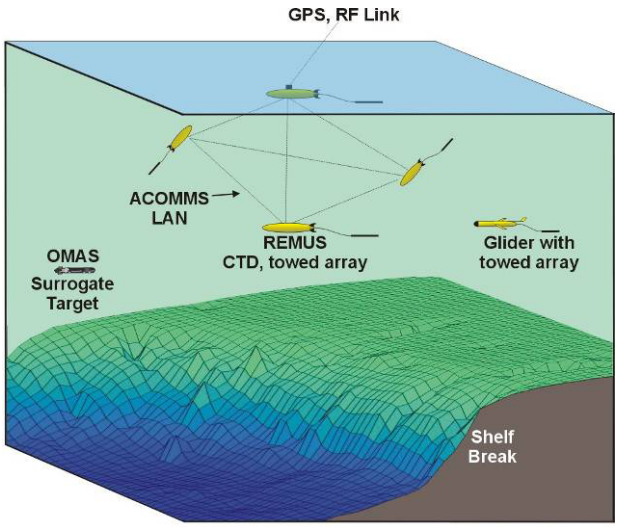

Figure 1. Concept for Autonomous Wide Aperture Cluster for Surveillance (AWACS): A cluster of REMUS vehicles and glider, each linked via AComms LAN, collaborating as a wide aperture system, to sense the ocean and bottom environment, and acoustics and ultimately to detect, classify and localize (DCL) surface and underwater vehicles.

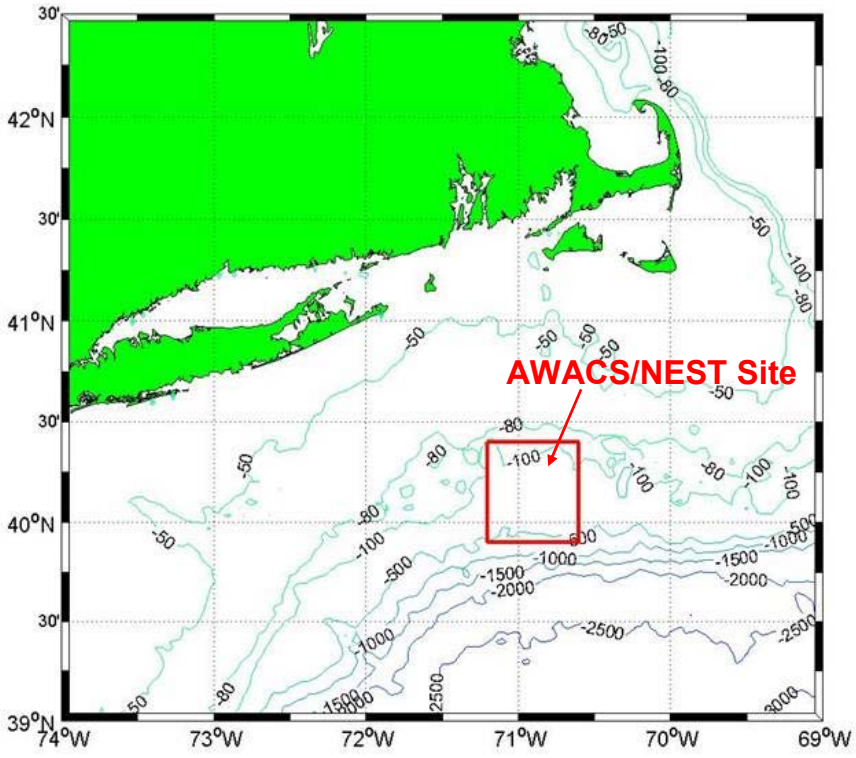

Figure 2. New England Shelfbreak Test (NEST 07)/AWACS Test Area.

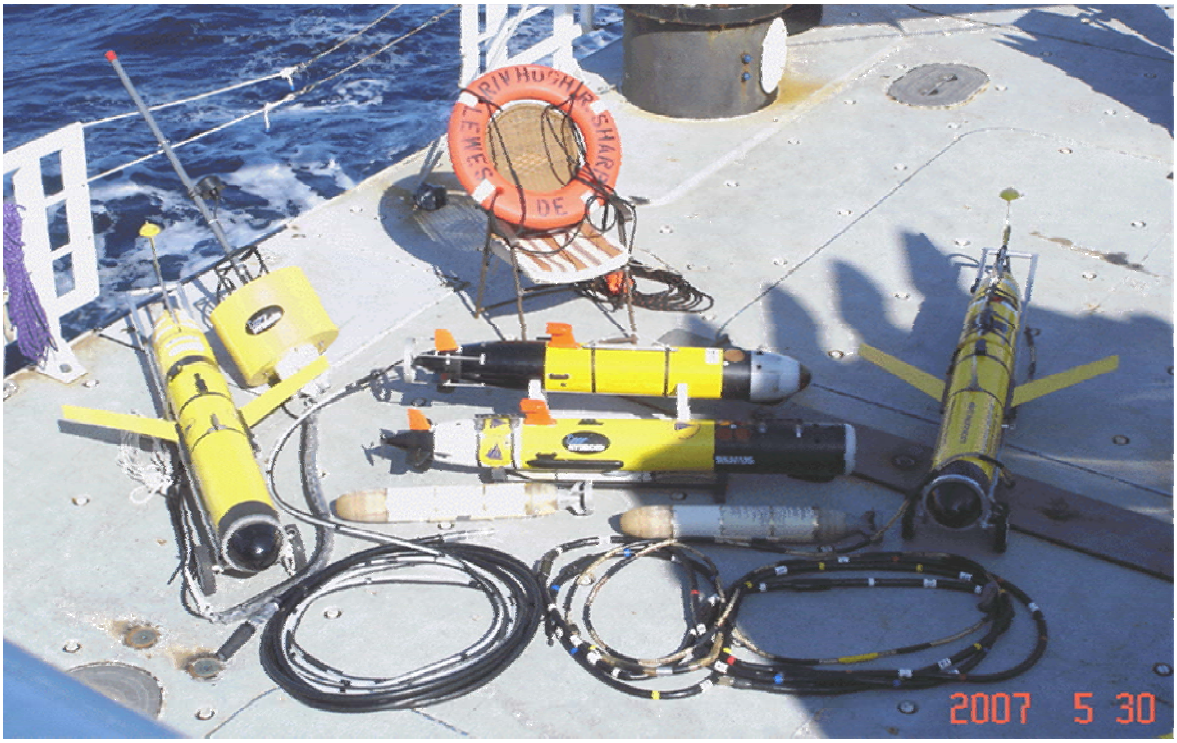

Figure 3. AWACS cluster, including two REMUS vehicles (one with acoustic system), two Gliders (one with acoustic system). Multiple OMAS vehicles with sonobuoy receivers and a gateway buoy.

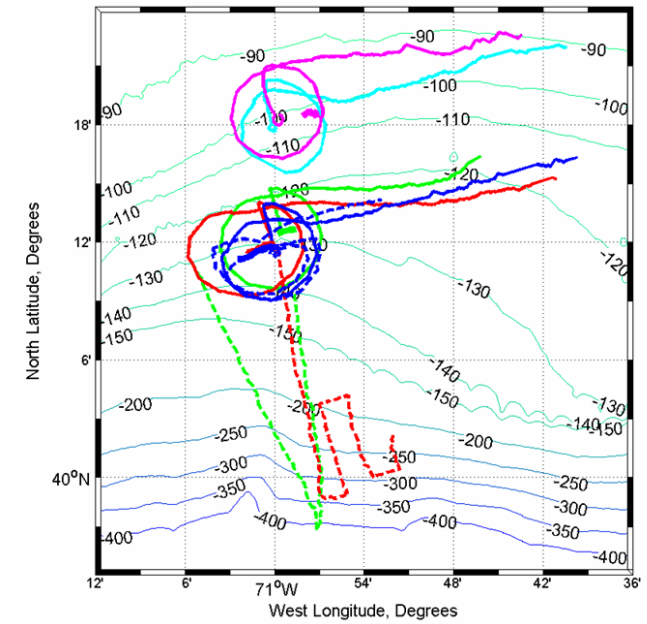

Figure 4. NEST07 operation area, with bathymetry and reconstructed OMAS tracks for the 8 runs. The OMAS tracks were selected based on objective maps from the measured oceanography and ocean adaptive sampling of environmental keys (i.e. Shelfbreak cross-shelf position, cold pool duct and mixed layer depth).

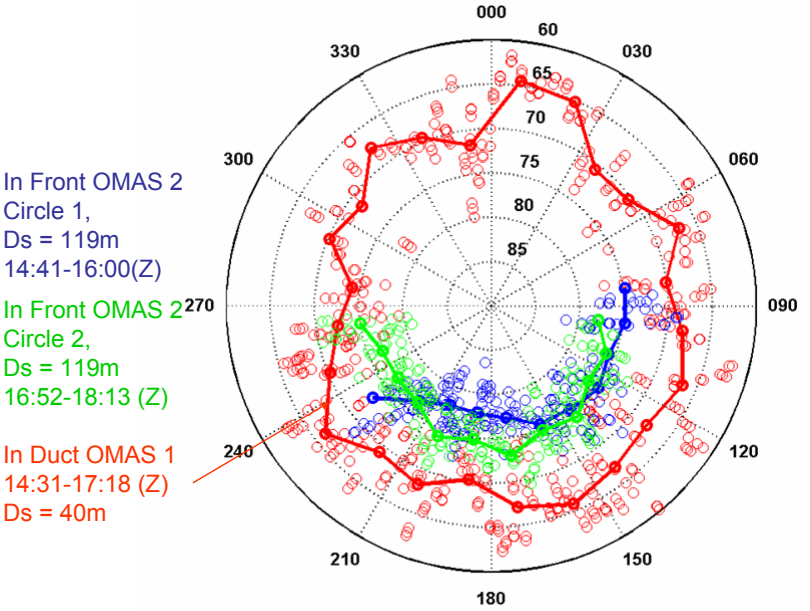

Figure 5. May 30 TL vs bearing results for two different OMAS vehicles, one transmitting within the cold pool duct (red) and the other transmitting below the duct (blue and green). The figure shows that a 5-10dB reduction in loss was realized by positioning the source within the duct.

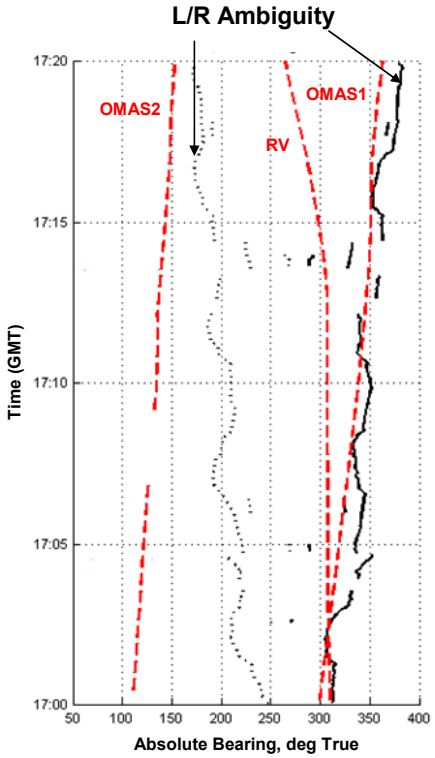

Figure 6. Measured Autonomous OMAS Bearing Tracks (Solid black line) w/Ground Truth (Dashed red line). The ambiguous OMAS1 track is also shown (Dotted black line)